CONTRIBUTIONS FROM THE LABORATORY OF VERTEBRATE BIOLOGY

University of Michigan, Ann Arbor, Michigan

Number 62 February, 1953

# THE STATISTICAL CONCEPT OF HOME RANGE AS APPLIED TO THE RECAPTURE RADIUS OF THE DEERMOUSE (PEROMYSCUS)

By LEE R. DICE and PHILIP J. CLARK

Accepted for publication October 7, 1952

## CONTENTS

Introduction . . . . . 1
General Considerations . . . . . 2
Statistical Treatment of Recapture Radii . . . . . 2
Application to Trapping Records of the Deermouse . . . . . 6
Relation of Certain Factors to Recapture Radius . . . . . 11
Summary . . . . . 13
Literature Cited . . . . . 14

## INTRODUCTION

A KNOWLEDGE of the area occupied by an individual animal in a population is of high ecologic interest. The area occupied affects population density, competition between individuals, reproductive success, utilization of food and other resources, social organization, relations between species, and other features of community dynamics.

In recent years numerous studies have been made of the home ranges of certain kinds of animals, and various methods have been developed for measuring home-range area (Burt, 1940; Blair, 1940; Dice, 1951; Haugen, 1942; Hayne, 1949). Most of these methods have assumed a more or less rigid boundary for each home range. It is recognized that an individual may sometimes be found at a considerable distance outside its usual home range, but it is almost impossible to decide which records are "unusual" and which are regular. The statistical treatment of the records has consequently been difficult.

To replace the idea that each home range has a fixed boundary, if only this boundary could be ascertained, Hayne (1949) has introduced the concept of a "center of activity" and has considered the probability of capturing an animal at various distances from this center. In general, the greater the distance from the center of activity, the lower is the probability of capturing the animal. Aside from the presence of physical barriers, however, there exists no boundary beyond which a given animal may not pass. If an animal has no fixed limits to its wanderings, the attempt to ascertain home-range boundaries or home-range areas is futile.

We here utilize Hayne's concept of home range, and we extend this concept by suggesting a more precise and a more general method for estimating the probability associated with any specified distance from the center of activity.

We are jointly responsible for developing the concepts here used and have collaborated in writing the paper. We are indebted to Professor C. C. Craig, of the University of Michigan's Statistical Research Laboratory, for critically reading the manuscript.

## GENERAL CONSIDERATIONS

As an animal travels over its home area it occupies an infinite number of positions, which may be called "activity loci." For any given period of time there exists for these loci (in two-dimensional Cartesian space) a geometric center, the "center of activity" of that animal. The distance between an activity locus and the center of activity may be called the "activity radius." In order to estimate the probability that an activity radius taken at random for a given individual will exceed a certain value, it is necessary to have a random sample of that individual's activity loci.

The activity loci successively occupied by a diurnal animal in its movements over its home range can often be ascertained by direct observation. A random sample of its activity loci can consequently be obtained by recording its position at random instants of time. Records of activity loci taken at regularly spaced instants, however, should give a sufficiently close approach to a random sample for all practical purposes, providing the various loci are essentially independent of one another.

## STATISTICAL TREATMENT OF RECAPTURE RADII

For many species of animals it is impractical to ascertain the activity loci in any way other than by the retrapping of marked individuals. For securing information about the movements of such animals a grid of traps may be extended over an area sufficiently large to include all the activity loci of at least one individual. The presence of the traps, however, modifies the movements of the animals to some extent, so that the activity loci and the center of activity ascertained from trapping records may not be fully descriptive of the movements over its home range of an uninhibited animal.

The following discussion will be restricted to a consideration of the distance between a given recapture locus and the geometric center of all the recapture loci which are recorded for a particular grid of traps

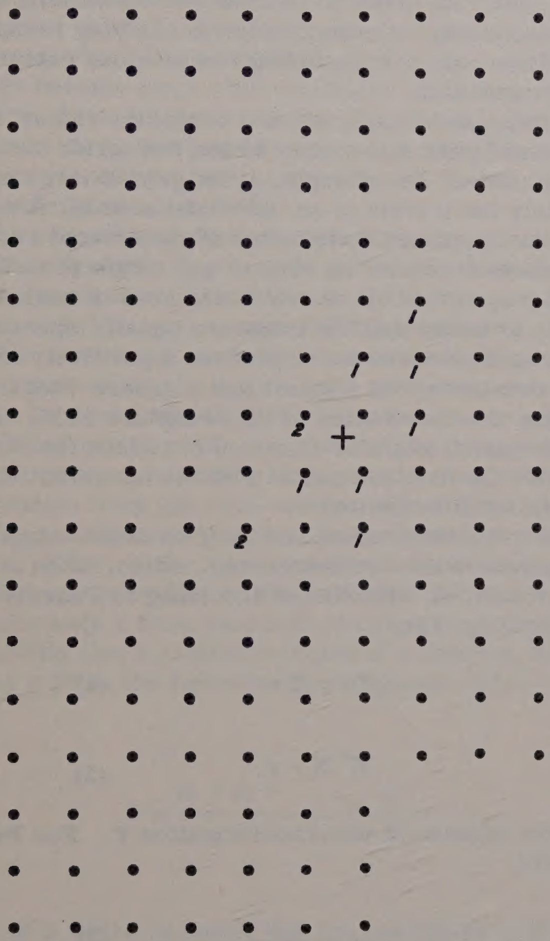

Fig. 1 Trap positions and recapture loci for adult female No. 1122, Peromyscus maniculatus bairdi, during October, 1951, on old-field study plot, E. S. George Reserve, Livingston County, Michigan. The cross marks the location of the recapture center. Distance between traps is 20 yards.

for a given individual. For brevity this distance is called the "recapture radius." The geometric center of the recapture loci is termed the "recapture center." These statistics are related to but differ somewhat from the respective center of activity and activity radius of the individual concerned. It should be pointed out that the various recapture radii for an individual are not independent of one another, since each recapture radius is a function of the recapture center. Accordingly, some small adjustment in the degrees of freedom for the variance of the recapture radii should probably be made (Fig. 1). Such an adjustment, however, has not been attempted in this paper.

Should an animal have been captured only once, its recapture radius is necessarily zero. Such a datum provides information concerning the activity center, but gives no information concerning the recapture radius of the individual. Consequently, in studying recapture radii it is useful to utilize only data including two or more captures of the same marked individual.

No upper limit can be assigned to a recapture radius, except that which is imposed by the dimensions of the trap grid; but the minimum value is always zero. Accordingly, if the grid is large enough to include completely the travels of an individual animal, it will not be surprising if the frequency distribution of the several recapture radii is positively skewed. Since the area of any circle of radius R is $\pi R^2$, the number of traps available in a circular area of radius $R^{1/2}$ is proportional to R, provided that the traps are equally spaced over the area; and this fact might also operate to produce a positively skewed distribution. Such considerations suggest that a square-root transformation might normalize the distribution of the recapture radii. At any rate, such a transformation might be expected to reduce the skewness sufficiently to enable the data to be used with the tabulated part of Pearson's type III probability distribution.

Let r be the recapture radius and let T be some transformation (such as the square-root transformation), which, when applied on r, produces a variable, X, distributed according to Pearson's type III probability function. Thus:

$$Tr = X \qquad (1)$$

and

$$T^{-1} X = r, \qquad (2)$$

where $T^{-1}$ is the inverse of the transformation T. For Pearson's type III function:

$$c = \frac{\epsilon - \mu}{\sigma} \qquad (3)$$

whence

$$\epsilon = \sigma c + \mu, \qquad (4)$$

where $\mu$ and $\sigma$ are the mean and standard deviation, respectively, of the population of X's, c is the standard variate of the Pearson type III distribution, and $\epsilon$ is any specified value.

If $\mu$ and $\sigma$ were known, one could calculate, from equation (3) and a table of Pearson's type III distribution (with the proper skewness), the probability that a randomly chosen X would be less than $\epsilon$. By using equation (4) together with the probability tables that value $\epsilon$ which is greater than a given proportion of the X's could be calculated. Having accomplished this, one could apply $T^{-1}$ on X to obtain equivalent statements for r. In reality, however, neither $\mu$ nor $\sigma$ can be known. These parameters can only be estimated. Consequently, from equation (3) one can only estimate the probability that a randomly chosen X will exceed a specified value $\epsilon$, and from equation (4) one can only estimate that value $\epsilon$ which is exceeded by a given proportion of the X's. As the samples become larger the estimates improve, so that for samples of fair size, over 30, for example, the estimates of $\mu$ and $\sigma$ may be fairly close to the actual parameters. For samples of such size, formulas (3) and (4) will provide acceptable and useful estimates of the probabilities and distances desired.

Although the preceding statements concern only the recapture radius of a particular individual, they may be generalized to treat the recapture radius of a population of individuals. For this purpose at least 2 recaptures per individual are required for a number of animals. When one individual is concerned, an attempt is made to ascertain the probability that a capture taken at random from the total number (>1) of captures available for that individual will be at a distance greater than r from the recapture center of the individual. On the population level we are concerned with the probability that a random capture of an individual taken at random from the total number of individuals available in the area will be at a distance greater than r from that individual's recapture center. Thus, if the area contains individuals $I_1, I_2, \ldots I_i, \ldots I_n$, and if for individual $I_i$ the probability that a random capture will exceed a distance r from that individual's recapture center is $p_i$, then the probability that a random capture of a random individual will be greater than r from the individual's recapture center is:

$$P = \frac{p_1 + p_2 + \ldots + p_n}{n} .$$

It is the value of P which is sought for the population of animals. Unfortunately, the data available are usually too meager to permit accurate estimation of the $p_i$, and in such cases P cannot be ascertained by the rigorous method outlined above. We believe, however, that a reasonable approximation to P can be obtained by simply pooling all of the recapture radii obtained from the population and obtaining estimates of $\mu$ and $\sigma$ from this pooled sample. We recognize that the validity of this procedure depends upon the assumption that the recapture radii for all of the animals form a single universe, which assumption we know to be not quite true. Nevertheless, this procedure has been followed in our study, in the belief that the error introduced by it is not appreciable.

## APPLICATION TO TRAPPING RECORDS OF THE DEERMOUSE

To illustrate these ideas we have applied them to a set of trapping records of the prairie deermouse (Peromyscus maniculatus bairdi) from an old-field community on the Edwin S. George Reserve in southern Michigan. The trapping records have been kindly furnished to us by Francis C. Evans. A 10 x 17 matrix of traps, spaced 20 yards apart, was extended over this area. Each day the traps were checked

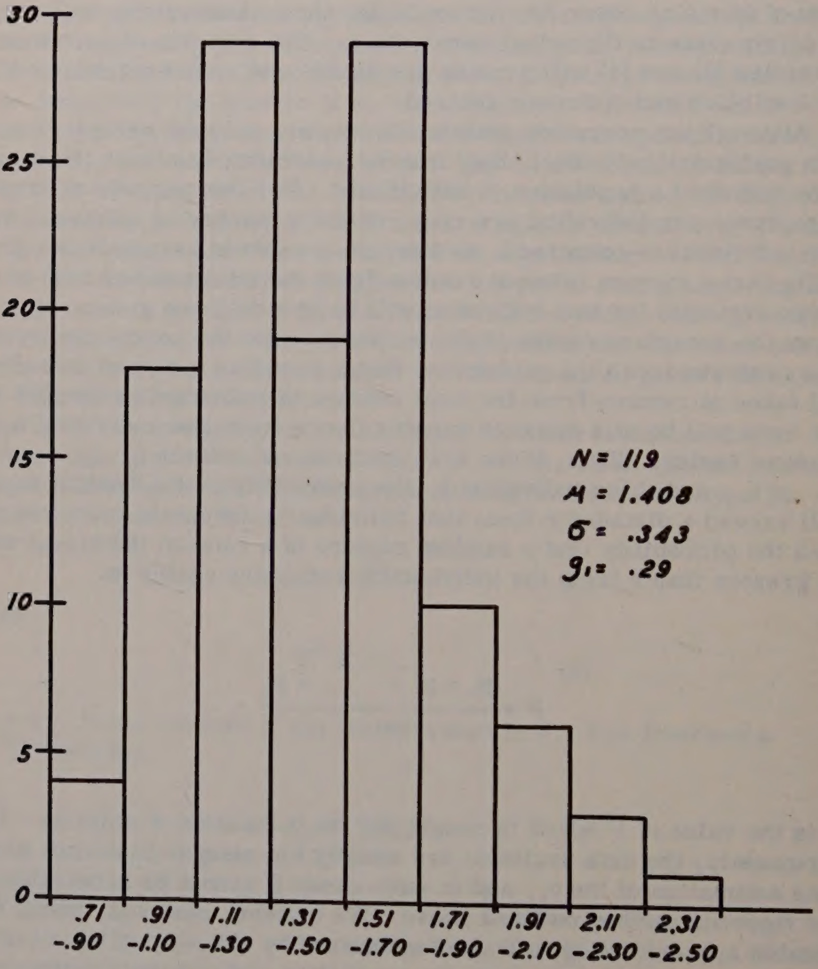

Fig. 2 Frequency histogram of square roots of recapture radii (1/2 distance between traps added to each recapture radius) in units of trap spacing (=20 yards); adults of Peromyscus maniculatus bairdi; during October of the four years 1948-51; on E. S. George Reserve, Livingston County, Michigan.

and each captured animal was marked, released, and its location recorded. This procedure was carried out for from 6 to 12 days in October of each of the four years 1948-51, inclusive (Fig. 2). Animals captured in peripheral traps were omitted from this study. During these periods 37 animals were captured two or more times, and a total of 185 recaptures was obtained. For each animal which was captured twice or oftener the geometric center of capture and the distance r of each capture from this center were calculated. In this manner 185 recapture radii were obtained. The square-root transformation was applied on r to produce a variable X (Table I). That is:

$$X = (r + 1/2)^{1/2} .$$

The 1/2 is added to each r before taking the square root as a correction for continuity (Kenney and Keeping, 1951, p. 253). Fisher's g statistics were applied to X in order to ascertain whether the distribution of the X's is nonnormal. The following results were obtained:

$$g_1 = .400 \qquad \sigma_{g_1} = .179 \qquad \frac{g_1}{\sigma_{g_1}} = 2.2$$

$$g_2 = -.093 \qquad \sigma_{g_2} = .356 \qquad \frac{g_2}{\sigma_{g_2}} = -0.3 .$$

It is seen that although $g_1$ differs significantly from 0 at the 5 per cent level, indicating positive skewness, $g_2$ does not so differ, indicating an absence of kurtosis. Consequently, an attempt may be made to fit X to the Pearson type III distribution. It is found that $\mu = 1.374$, $\sigma = .315$, and $\alpha_3 = .400$. Consequently, the deviation from the mean in units of $\sigma$ is:

$$c = \frac{\epsilon - 1.374}{.315} .$$

This provides an estimate of the probability that a randomly chosen X will be less than any specified value $\epsilon$, and the equation $\epsilon = .315c + 1.374$ will give an estimate of that value $\epsilon$ which is greater than a proportion P of the X's. For illustration the estimation of those values which are exceeded, respectively, by 25 per cent and 50 per cent of the X's will be described. From page 18 of Carver's tables (1940) it is found by interpolation for $\alpha_3 = .4$ and $P = .250000$ that c (called t in Carver's notation) $= -.706$. Thus, in this case $\epsilon = (.315)(-.706) + 1.374 = 1.15$. For $\alpha_3 = .4$ and $P = .500000$, it is found on page 20 that $c = -.067$, whence $\epsilon = (.315)(-.067) + 1.374 = 1.35$, and so

TABLE I

Transformed recapture radii for the prairie deermouse. Square-root transformation of distance of each recapture center of that individual, in units of space between traps.

| Class and Individual Number | Recapture Order | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1948 | | | | | | | | | | | |
| Adult ♀♀ | | | | | | | | | | | |
| 0004 | .80 | 1.67 | 1.64 | 2.12 | 1.23 | 1.35 | | | | | |
| 0023 | 1.14 | .92 | 1.14 | .92 | | | | | | | |
| Adult ♂♂ | | | | | | | | | | | |
| 0005 | 1.51 | 1.40 | 1.51 | 1.55 | 1.14 | 1.51 | 1.81 | 1.14 | | | |
| 0003 | 1.30 | 1.30 | 1.66 | 1.65 | 1.93 | 1.66 | 1.27 | 2.00 | 1.76 | | |
| 0015 | 1.24 | 1.62 | 1.62 | 1.12 | 1.45 | 1.62 | 1.45 | 1.24 | | | |
| Juvenile ♀♀ | | | | | | | | | | | |
| 0022 | 1.00 | 1.00 | | | | | | | | | |
| 0021 | 1.56 | 1.47 | .91 | | | | | | | | |
| 0002 | 1.85 | 1.10 | 1.59 | 1.10 | 1.10 | 1.46 | 1.13 | 1.59 | 1.76 | | |
| Juvenile ♂♂ | | | | | | | | | | | |
| 0024 | 1.10 | 1.10 | | | | | | | | | |
| 0020 | 1.18 | 1.18 | 1.48 | 1.02 | | | | | | | |
| 1949 | | | | | | | | | | | |
| Adult ♀♀ | | | | | | | | | | | |
| 0043 | 1.08 | .91 | .91 | | | | | | | | |
| 0044 | 1.57 | 1.57 | 1.52 | 1.98 | 1.65 | | | | | | |
| 0034 | 1.31 | 1.24 | 1.24 | .89 | 1.24 | 1.46 | 1.58 | | | | |
| Adult ♂♂ | | | | | | | | | | | |
| 0041 | 1.60 | 1.23 | 1.96 | 1.86 | 1.68 | | | | | | |
| 0040 | 1.26 | 1.29 | 1.26 | 1.29 | 1.03 | 1.72 | 2.13 | | | | |
| Juvenile ♀♀ | | | | | | | | | | | |
| 0042 | 1.26 | 1.29 | 1.59 | 1.61 | 1.59 | | | | | | |
| 1950 | | | | | | | | | | | |
| Adult ♀♀ | | | | | | | | | | | |
| 0114 | 1.65 | 1.65 | 1.38 | 1.38 | | | | | | | |
| 1030 | 1.14 | 1.40 | .92 | 1.14 | | | | | | | |
| 0123 | 1.96 | 1.71 | 1.63 | 2.18 | 1.33 | | | | | | |
| 1000 | 1.31 | 1.15 | 1.48 | 1.57 | 1.15 | | | | | | |

TABLE I (Cont.)

| Class and Individual Number | Recapture Order | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Adult ♂♂ | | | | | | | | | | | |
| 0113 | 1.66 | .92 | .92 | 1.83 | | | | | | | |
| 0041 | 1.06 | 1.45 | .97 | 2.08 | 1.58 | | | | | | |
| Juvenile ♀♀ | | | | | | | | | | | |
| 1034 | 1.31 | 1.08 | 1.47 | | | | | | | | |
| 1032 | 1.40 | .92 | 1.14 | 1.14 | | | | | | | |
| 1025 | 1.16 | 1.39 | 1.16 | 1.11 | 1.72 | | | | | | |
| 0042 | 1.68 | .91 | 1.25 | 1.47 | 1.83 | 1.35 | | | | | |
| 0122 | 1.33 | 1.21 | 1.01 | 1.01 | 1.33 | 1.55 | | | | | |
| 1024 | 1.21 | 1.01 | 1.55 | 1.01 | 1.33 | 1.33 | | | | | |
| Juvenile ♂♂ | | | | | | | | | | | |
| 1031 | 1.25 | 1.35 | 1.56 | | | | | | | | |
| 1033 | 1.25 | 1.55 | 1.66 | 1.33 | | | | | | | |
| 1024 | 1.66 | .92 | 1.14 | 1.55 | | | | | | | |
| 1951<br>Adult ♀♀ | | | | | | | | | | | |
| 1132 | 1.00 | 1.00 | | | | | | | | | |
| 1131 | 1.00 | 1.00 | | | | | | | | | |
| 1135 | 1.47 | 1.83 | 1.35 | | | | | | | | |
| 1120 | .95 | 1.29 | .95 | 1.90 | 2.41 | 1.29 | 1.55 | 1.05 | 1.76 | 1.45 | |
| 1122 | 1.68 | 1.11 | 1.80 | 1.56 | 1.11 | 1.38 | 1.38 | 1.68 | 1.19 | 1.11 | 1.48 |
| Adult ♂♂ | | | | | | | | | | | |
| 1124 | .71 | .71 | | | | | | | | | |

forth. Thus, if P denotes any selected probability it is found that:

$$
\begin{aligned}
P\ (X < 1.15) &= .25\\
P\ (X < 1.35) &= .50\\
P\ (X < 1.57) &= .75\\
P\ (X < 1.93) &= .95\\
P\ (X < 2.20) &= .99
\end{aligned}
$$

Subtracting 1/2 from $X^2$ gives the following statements for the recapture radius (r):

$$P\ (r < .82) = .25$$
$$P\ (r < 1.32) = .50$$
$$P\ (r < 1.96) = .75$$
$$P\ (r < 3.22) = .95$$
$$P\ (r < 4.34) = .99$$

Similar estimates may be made for any other probability.

In the equations given above r is expressed in units of 1 trap space, that is, 60 feet, since the traps were spaced 60 feet apart in the grid. These equations allow the prediction that 25 per cent of the recaptures of the prairie deermouse from this grid will be less than 49 feet (i.e. .82 x 60) from the recapture center of the captured individual. Likewise, it can be predicted that 50 per cent of the recaptures will be less than 79 feet from the recapture center; 75 per cent of them will be less than 118 feet from this center; 95 per cent less than 193 feet; and 99 per cent will be less than 260 feet from it.

It can also be estimated that 25 per cent of the recaptures will be included in a circular area of 7605 square feet ($3.1416 \times .82^2 \times 60^2$) which is symmetric about the recapture center of the captured individual; 50 per cent of the recaptures will be included in a circular area of 19706 square feet symmetric about this center; 75 per cent within a circular area of 43448 square feet; 95 per cent within an area of 117,264 square feet; and 99 per cent within an area of 213,026 square feet. But these statements do not in any way imply that all parts of any circular area are equally occupied. It would certainly be desirable to know a great deal more about the movements of an animal than is provided in the statements given above. Nevertheless, these statements provide some useful information about the movements of the animals in question. Detailed statements will probably have to await more data.

It might be pointed out that the absence of platykurtosis in the pooled data suggests the validity of the assumption that these animals have no fixed home-range boundaries. Should there be a physical barrier to movement in one or more directions from the center of activity of an individual animal, this would be expected to result in limitation of the recapture radii in that direction or directions. Likewise, if the animals defend territories, their movements would be to that extent restricted and their recapture radii limited. In either case the result should be the occurrence of a certain amount of kurtosis in the frequency curve for the recapture radii. The absence of such kurtosis in our measurements indicates that home ranges of the prairie deermice on the trapping plot under consideration are not limited either by physical barriers or by territorial defense.

In order to ascertain how well the pooled data fit the Pearson type III distribution, a $\chi^2$ test of goodness of fit was applied to them, using $\sigma = .315$, $\mu = 1.374$, $\alpha_3 = .40$, and appropriate values of c. Partitioning the data into 15 classes resulted in a $\chi^2$ of 20.28, which, at the 5 per cent level, indicates significant heterogeneity. The existence of this heterogeneity suggests the desirability of investigating the effect of various factors upon the recapture radius.

## RELATION OF CERTAIN FACTORS TO RECAPTURE RADIUS

Although the distribution of X is not normal at the 5 per cent level, it is considered that normality is approached sufficiently closely to enable a series of one-way analyses of variance to be applied to it.

The X's were first classified according to the years 1948, 1949, 1950, and 1951. A one-way analysis of variance reveals that the means of the X's for the various years do not differ significantly from one another at the 5 per cent level.

The 185 X's were next classified according to whether they pertained to ♂♂ or to ♀♀. The mean of the X's for the ♂♂ was 1.41 trapping units, and for the ♀♀, 1.35 trapping units; but the difference between the means of the 2 sexes is not significantly different from 0 at the 5 per cent level.

The X's were also classified according to age class, i.e., juvenile and adult. The mean of the X's for juveniles was 1.31 trapping units, for adults 1.41 trapping units; and the difference between these 2 means is significantly different from 0 at the 5 per cent level. Because the poor fit of the pooled data to the hypothetical distribution might be the result of combining juveniles with adults, these 2 age classes were now separately fitted. For juveniles $\sigma = .249$, $\mu = 1.312$, and $\alpha_3 = .26$. Partitioning them into 9 classes gave a $\chi^2$ of 4.38, for which $.30 < P < .50$, indicating a satisfactory fit. For adults $\sigma = .343$, $\mu = 1.408$, and $\alpha_3 = .29$. Partitioning the adults into 11 classes resulted in a $\chi^2$ of 7.57, for which, as with juveniles, $.30 < P < .50$, likewise indicating a satisfactory fit. It would appear desirable, therefore, to make estimates for juveniles and adults separately, whenever the data are sufficiently numerous to do so. Thus for juveniles:

$$P\left[\begin{matrix}X\\ r\end{matrix} < \begin{matrix}1.15\\ .82\end{matrix}\right] = .2658$$

$$P\left[\begin{matrix}X\\ r\end{matrix} < \begin{matrix}1.35\\ 1.32\end{matrix}\right] = .5763$$

$$P\left[\begin{matrix}X\\ r\end{matrix} < \begin{matrix}1.57\\ 1.96\end{matrix}\right] = .8507$$

$$P\left[\begin{matrix}X\\ r\end{matrix} < \begin{matrix}1.93\\ 3.22\end{matrix}\right] = .9892$$

$$P\left[\begin{matrix}X\\ r\end{matrix} < \begin{matrix}2.20\\ 4.34\end{matrix}\right] = .9992$$

and for adults:

$$P\left[\begin{matrix} X \\ r \end{matrix} < \begin{matrix} 1.15 \\ .82 \end{matrix}\right] = .2326$$

$$P\left[\begin{matrix} X \\ r \end{matrix} < \begin{matrix} 1.35 \\ 1.32 \end{matrix}\right] = .4511$$

$$P\left[\begin{matrix} X \\ r \end{matrix} < \begin{matrix} 1.57 \\ 1.96 \end{matrix}\right] = .6942$$

$$P\left[\begin{matrix} X \\ r \end{matrix} < \begin{matrix} 1.93 \\ 3.22 \end{matrix}\right] = .9290$$

$$P\left[\begin{matrix} X \\ r \end{matrix} < \begin{matrix} 2.20 \\ 4.34 \end{matrix}\right] = .9838$$

By taking the weighted mean of the juveniles and the adults for each of the above categories the following equations are obtained:

$$P\left[\begin{matrix} X \\ r \end{matrix} < \begin{matrix} 1.15 \\ .82 \end{matrix}\right] = .24$$

$$P\left[\begin{matrix} X \\ r \end{matrix} < \begin{matrix} 1.35 \\ 1.32 \end{matrix}\right] = .50$$

$$P\left[\begin{matrix} X \\ r \end{matrix} < \begin{matrix} 1.57 \\ 1.96 \end{matrix}\right] = .75$$

$$P\left[\begin{matrix} X \\ r \end{matrix} < \begin{matrix} 1.93 \\ 3.22 \end{matrix}\right] = .95$$

$$P\left[\begin{matrix} X \\ r \end{matrix} < \begin{matrix} 2.20 \\ 4.34 \end{matrix}\right] = .99,$$

which results agree closely with those obtained from the pooled data.

The X's were finally classified according to whether the individual to which they pertained was captured a total of 2, 3, . . . , 11 times. An analysis of variance on this classification shows that the mean value of X for some of these categories differs significantly, at the 1 per cent level, from the mean value of X for other categories. Those animals captured fewer than 5 times had somewhat smaller recapture radii than those captured a greater number of times. It was suspected that this result might be caused by the fact that, in general, the more times an animal was caught, the greater the time interval between the first and last capture. If each individual's center of activity is absolutely fixed, and if the time interval between captures is sufficient to ensure that the positions of successive captures are essentially independent of one another, then the interval between the first and last capture should not bias the recapture radius. But if, as seems more likely, an individual's center of activity shifts somewhat with time, or if the interval between captures is so small that successive captures are not independent of one another, then one might expect the mean recapture radius to increase with the interval between captures. It was found that the interval between the first and last captures varied from 1 day to 15 days. An analysis of variance reveals a significant relationship, at the 5 per cent level, between the recapture radius and the interval between the first and last captures. Consequently, it would be most desirable if all of the data were uniform in this regard. If, however, only those records which were collected over a constant time interval were used, the data would be so greatly reduced that the final result would probably be less accurate than that obtained by pooling all of the recapture radii based on two or more captures.

It should be emphasized that any statements about recapture radii must apply only to a particular kind of animal in a particular location during a specified period, or periods, of time, and captured in a particular trap grid. The effect of variation in these factors upon the recapture radius can be learned only by experimentation. The effects of variation in year and likewise the effects of age class and of sex have been considered briefly. It would be interesting also to compare data from different localities. An especially interesting question is the effect of different trap spacings on the recapture radius. Hayne (1950) has found that the mean recapture radius of male meadow voles (Microtus) increases with the distance between traps, but such a relationship was not observed for the females. It seems certain that the distance between traps will influence the recapture radius, since if the traps are very far apart nearly all of the recapture radii will be zero; if the traps are quite close together they may hinder the movements of the animals to a great extent, thus perhaps reducing the recapture radius. But these matters require further experimental investigation.

Although our interest has been more in activity radii than in recapture radii, from the data available all of our knowledge of the former must be derived from the latter. It is likely that the mean activity radius is about 1/2 of a trap space greater than the corresponding mean recapture radius, since an animal probably wanders farther from its center of activity than the most distant trap in which it is caught, and it is probable that $X^2$ is a better estimate of the activity radius than is r. It should be re-emphasized, however, that nothing whatever can be learned from these data about the activity radii of animals which have not been influenced by the presence of traps.

## SUMMARY

In the statistical concept of home range each animal is assumed to have a center of activity but no fixed outer limits to his range, except such as may be imposed by physical or biological barriers to his movements. In general, the greater the distance from his center of activity, the lower is the probability of the occurrence of that individual.

An "activity locus" is defined as one of an infinite number of points

occupied by an animal in its movements over its home range. The "center of activity" is the geometric center of all of the activity loci. The distance between an activity locus and the center of activity for an individual is called an "activity radius." A "recapture locus" is defined as one of a finite number of points at which an animal is captured, and the "recapture center" is the geometric center of all of the recapture loci. The distance between a recapture locus and the recapture center is a "recapture radius."

These concepts are applied to the records of recapture of marked prairie deermice (Peromyscus maniculatus bairdi) on a grid of traps spaced at 60-foot intervals over a relatively uniform habitat on the Edwin S. George Reserve in southern Michigan. The square-root transformation, when applied to the several recapture radii, produces a variable, X, whose frequency distribution does not depart greatly from normality. Analysis of variance on the transformed variable, X, reveals no significant differences in mean recapture radii for the years 1948, 1949, 1950, and 1951. Males have a somewhat greater recapture radius than females, though the difference is not significant at the 5 per cent level. The recapture radius of adults is significantly greater at the 5 per cent level than that of juveniles. By use of Pearson's type III probability function it is estimated that of the recaptures of the prairie deermouse under the trapping conditions specified, 25 per cent will be within 49 feet of the recapture center, 50 per cent within 79 feet, 75 per cent within 118 feet, 95 per cent within 193 feet, and 99 per cent within 260 feet.

## LITERATURE CITED

BLAIR, W. FRANK

1940 Home ranges and populations of the meadow vole in southern Michigan. Journ. Wildlife Management, 4:149-61.

BURT, WILLIAM H.

1940 Territorial behavior and populations of some small mammals in southern Michigan. Misc. Publ. Mus. Zool. Univ. Mich., 45:1-58.

CARVER, HARRY C.

1940 Statistical tables. Ann Arbor: Edwards Bros.

DICE, LEE R., and WALTER E. HOWARD

1951 Distance of dispersal by prairie deermice from birthplaces to breeding sites. Contrib. Lab. Vert. Biol. Univ. Mich., 50:1-15.

EVANS, FRANCIS C., and STANLEY A. CAIN

1952 Preliminary studies on the vegetation of an old-field community in southeastern Michigan. Contrib. Lab. Vert. Biol. Univ. Mich., 51:1-17.

HAUGEN, ARNOLD O.

1942 Home range of the cottontail rabbit. Ecology, 23:354-67.

HAYNE, DON W.

1949 Calculation of size of home range. Journ. Mammalogy, 30:1-18.

1950 Apparent size of home range of Microtus in relation to distance between traps. Ibid., 31:26-39.

KENNEY, J. F., and E. S. KEEPING

1951 Mathematics of statistics, Pt. II. New York: D. Van Nostrand Co.

Copies of this contribution may be purchased from the University of Michigan Press, Ann Arbor, Michigan. Price $0.25.